Patent Application of

Michael K. Fitch

for

Title: Method and Apparatus for Reclamation of Precious Metals from Circuit Board Scrap

Federally Sponsored Research:

Not Applicable

Sequence Listing or Program:

Not Applicable

Background - Field of Invention:

This invention generally relates to reclamation of precious metals from circuit board scrap. More specifically this invention relates to dramatic improvements to the state of the art reclamation methods resulting from the breakthrough discovery that much more benign chemicals can be used for separation of unwanted metals, leaving only desired metal, when combined wanted and unwanted scrap metals are immersed in chemical baths that are subjected to an electromagnetic field at specific frequencies and power levels during processing.

Prior Art:

The prior art discloses several different processes for recovery of precious metals from circuit board scrap all of which require a multitude of processing steps and equipment.

The first commonly used process is a complex dry process which involves pulverizing, crushing metals-containing scrap circuit boards into a fine powder, magnetic separation, electrostatic separation, air table separation and gravimetric separation. These processes are time consuming, capital intensive, require large machines, lots of floor space, dust collection systems, are labor intensive and only prepare the metal alloyed powders for further wet chemical and/or electrolytic separation. These processes are disclosed in Drage (U.S. Pat. No. 3,885,744), Drage (U.S. Pat. No. 3,905,556), Alavi (U.S. Pat. No. 5,139,203), Feldman (U.S. Pat. No.5,217,171), Izumikawa (U.S. Pat.

No.5,630,554), Yokoyama (U.S. Pat. No. 5,676,318), and Chapman (U.S. Pat. No. 5,887,805).

The second major process for precious metals reclamation from printed circuit boards involves a process where the circuit boards are pyrolized in a closed loop system consisting of a scrubber, bag house and incinerator. Theses processes are disclosed in Bickford (U.S. Pat. No. 5,662,579), Wicks (U.S. Pat. No. 5,843,287), Chang (U.S. Pat. No. 5,979,033), and Wicks (U.S. Pat. No. 6,143,139). The incinerated product is then placed into a crucible furnace with the proper fluxing agents and reduced to metal and cast into unrefined bars. The unrefined bars are then placed into a blast furnace to remove all deleterious components and subjected to further refining steps such as processing requiring wet chemicals and/or electrolysis for final separation.

The wet chemical stripping processes utilize strong hydrochloric, sulphuric and nitric acids and a caustic soda solution and/or electrolytic processes involving casting the alloyed metals into anodes and placing them in galvanic baths depending on the particular metal being reduced or stripped. All the above drawbacks are involved in this process plus an additional hazard to control of the dibenzo-p-dioxins and dibenzo-furans given off when the scrap is incinerated with a halogen flame. This can be a four month long process with many processing steps.

Behr Precious Metals, Inc. discloses in a conference paper presented at NEPCON West - 1994 entitled <u>Refining and smelting of precious metals from printed circuit boards</u> the third process, involving wet chemistry processes which subject surface plated boards and or parts to a cyanide stripping action in an agitated tumbler that allows the precious metals to be placed in solution, reclaimed from solution, refined and melted into bars. Environmental concerns may rule out this process in the future.

All of the above processes suffer from the following disadvantages:

(a) They all, with the exception of the cyanide stripping of surface plating, begin with the associated non-metal boards crushed into powder along with the metals or pyrolized with associated separation problems, expense and hazards.

(b) Once the metal fractions have been separated out from the non-metals then a slow wet chemistry and/or electrolytic process is required with multiple steps and baths

utilizing very strong acids and bases to separate the various metals, casting into anodes and subjecting the anodes to galvanic baths for final refinement.

(c) All these methods are capital and labor intensive.

(d) They all require significant floor space and energy consumption.

(e) They all require significant safeguards as to dust collection and waste chemical disposal.

Objects and Advantages:

Accordingly several objects and advantages of the present invention are:

(a) to provide a precious metals reclamation process that begins with separating metal runners and contacts from circuit boards and discarding bare board waste without mixing it in with metals to be separated later or pyrolyzing organic materials with inherent hazardous dioxins and furans.

(b) to provide a precious metals reclamation process that utilizes benign, environmentally friendly chemicals for separating copper and nickel and other trace metals from precious metals, leaving only desired metal, such as gold.

(c) to provide a precious metals reclamation process that that is a one step process.

(d) to provide a precious metals reclamation process that requires a small footprint and relatively inexpensive equipment.

(e) to provide a precious metals reclamation process that is not labor intensive.

(f) to provide a precious metals reclamation process that is rapid.

Further objects and advantages are to provide a precious metal reclamation which can be used easily and conveniently by a relatively unskilled operator with a high return on investment. Still further objects and advantages will become apparent from a consideration of the ensuing description and drawings.

Summary:

In accordance with the present invention, an improved method and apparatus for reclamation of precious metals from circuit board scrap comprises peeling metal runners and contacts from scrap circuit boards and placing the metal shavings in a leaded glass

beaker; filling the beaker with a muratic (weak hydrochloric) acid solution which is saturated with copper sulfate; introducing an electromagnetic field at specific frequencies and power levels; skimming the floating metal flake from the surface of the chemical solution; rinsing in water and denatured alcohol; compressing the flake; and melting and pouring into bars or nuggets for further use or sale.

The foregoing and other objects and advantages will appear from the description to follow. Reference is made in the description to the accompanying drawings which form a part hereof. The accompanying drawings show, by way of illustration, two specific embodiments in which the invention is practiced whereby the precious metal reclaimed is gold. These embodiments will be described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that structural changes, process control circuitry modification and automation may be made without departing from the scope of the invention. For example Figure 1-A shows a cathode drive control circuit as an alternative to the grid drive control circuit shown in Figure 1 which takes less power but does not give as precise control over wave forms generated. The size and shape of the apparatus shown in the attached drawings is for illustrative purpose only and is not intended to limit the application as to scaling that will be obvious to one skilled in the art of metals reclamation. Other embodiments can be utilized to reclaim other precious metals utilizing similar hardware but run at specific power levels and frequencies between 50 kilohertz and 1 megahertz for the desired metals such as silver, platinum, titanium, rhodium and palladium. In the accompanying drawings, like reference characters designate the same or similar parts throughout the several views.

Drawings:

Drawing Figures

FIG. 1 shows a schematic of a two kilowatt induction furnace with a grid drive control circuit for generating an electromagnetic field required to excite metal atoms and chemical ions and a v-shaped leaded glass beaker to hold the metal shavings and chemicals during processing.

FIG. 1-A shows a second embodiment with a cathode drive control circuit.

FIG. 2 shows a nonconductive-fluid based heat exchanger.

FIG. 3 shows a schematic of a push-pull power amplifier.

FIG. 4 shows a schematic of a power supply with controls.

FIG. 5 shows an oscillator.

FIG. 6 shows a voltage control oscillator

Reference Numerals In Drawings

10 – induction furnace

12 – heat exchanger

14 – non-conductive fluid

16 – large inductor

18 – v-shaped leaded glass beaker

20 – metal level

22 – 10 cm. long metal segments

24 – chemical solution (mild HCL, H_2O & copper sulfate)

26 – solution fill level

28 – Variac

30 – power supply with controls

32 – run switch

34 – tune switch

36 – push-pull power amplifier

38 – oscillator

40 – voltage control oscillator

42 – run level

44 – coolant pump & motor

46 – cathode drive control circuit

J1 – push- pull power amp. output

J2 – oscillator output

J3 – voltage control osc. output

J4 – power supply output

J5 – single phase 220 volt supply

X – output of cathode drive control circuit

Detailed Description:

The present invention springs from the discovery that mild acids could be utilized to shear undesired metals away at a high rate from the desired metal when acid solution and scrap metal segments are excited by application of an electromagnetic field at specific frequencies and power levels based on the end metal desired and the included metals to remove. When acid solutions saturated with copper sulfate are exited, sheared copper and nickel molecules are rapidly absorbed into solution, leaving only desired metal, such as gold, in a 99.5 % pure flake which can be skimmed off the surface of the solution or filtered from the solution.

The method and apparatus to accomplish the reclamation of the desired metals disclosed in this invention is much quicker, less than sixty minutes from start-up to pure precious metal output, simpler than prior art methods and apparatus and it generates no hazardous by-products. The output of this process is pure desired metal, not solutions containing the desired metals requiring further process steps to reclaim. Unwanted metal ions are sheared away precisely to the boundary between the desired and undesired metals allowing for a high, approximately 99.5 %, purity of desired metal remaining. The shearing acid is completely reusable after the unwanted metal salts are allowed to precipitate out. When the shearing solution has absorbed all the undesired metal it can, it is poured off and new solution added. This process is repeated, approximately five times for the present embodiment, until all undesired metal is sheared and absorbed and the remaining precious metal is left in 99.5% pure flake. The process can be monitored either by watching the color of the shearing fluid change from aqua to purple as the fluid saturates or by monitoring the reflected energy with a simple voltmeter. Metal runners 22 are typically 70 % copper, 10 % nickel, 10% gold and 10% other metals. The older the boards, the higher the % of gold will be.

Turning to the drawings for a more thorough explanation of the method and apparatus, the method is comprised of the steps of pealing the metal runners off of scrap circuit boards with a razor sharp device, not shown; dicing the metal runners into 10 cm long metal runner segments 22 with shears, not shown; collecting and compressing the runner segments into flat shapes; placing in leaded glass beaker 18 shown in Figures 1 and 2, until beaker 18 is approximately 2/3 full of scrap metal; filling beaker 18 with

chemical solution 24 (preferably muratic acid, water and copper sulfate with an approximate ratio of 2/3 water and 1/3 muratic acid and 1 pound of copper sulfate per gallon of solution); applying an electromagnetic field with modified induction furnace 10, stepping up the power from 0 to 400 watts with a controlled sine wave oscillator 38 set at approximately 13 kHz; controlling the temperature of chemical solution 24 at approximately 25 degrees centigrade, allowing the expansion of chemical solution 24 to run level 42 and the frequency to increase to approximately 30 kHz; shearing the copper molecules very quickly from the nickel or zinc layer and then the nickel or zinc layer from the gold plating. The inherent rise in temperature is controlled with heat exchanger 12 which circulates non-conductive fluid 14 through large inductor 16 adjacent to beaker 18. Iron and tin can be sheared by tuning the frequency between 7 and 13 kHz. More complex metals such as silver, platinum, palladium, rhodium and titanium can be sheared by tuning the frequency to between 50 kilohertz and 1 MHz. The process for gold reclamation ideally is started at 13 kHz where the reflected energy is about 5 to 1; as oscillator 38 ramps up to 30 kHz, the reflected energy drops to about 1 to 1 as metal segments 22 are absorbing all the power and aqua colored chemical solution 24 around metal segments 22 turns purple. Chemical solution 24 has absorbed all the copper, nickel and other metals that it can at that point and used chemical solution 24 is poured off and fresh chemical solution 24 is added to the beaker. The process is repeated two to five times, until chemical solution 24 maintains its aqua color throughout the cycle, finding no more copper, nickel or other metals. The pure gold flake which has floated to the surface of chemical solution 24 can then be readily filtered or skimmed off the surface, not shown. The gold flake can then be rinsed in water and denatured alcohol, compressed, melted and poured into bars or nuggets for later use or sale, not shown.

Basically there are no hazardous waste byproducts of this process. The used chemical solution 24 is stored in a precipitation vessel, not shown, for approximately two weeks. The copper, nickel and other metal salts precipitate out as sludge in the bottom of the vessel in a stratified manner and chemical solution 24 returns to its original aqua color indicating that it is ready for reuse.

If there is an interest in recovering the other metals from the remaining sludge, they can be refined by melting and using the unique melting points of the various metals,

separated through wet chemical and/or electrolytic processes or by taking advantage of the differences in specific gravities effecting the precipitation rates indicated by the stratification in the sludge of different metals.

An example of an embodiment that demonstrates this invention for gold reclamation is described as follows: a small, approximately 2 kilowatt, induction furnace 10 as shown in FIG. 1 is modified by adding a heat exchanger 12 as shown in FIG. 2 which circulates a non-conductive fluid 14, such as Glycol, with an electric motor and pump assembly 44 through large inductor 16, adjacent to a conical shaped leaded glass beaker 18.

Induction furnace 10 is also modified by adding wave shaping, frequency control and voltage control by connecting push–pull power amplifier 36 as shown in FIG. 3 at J1 by closing tune switch 34 and opening run switch 32 as shown in FIG. 1. Oscillator 38 which is shown in FIG. 5 is connected at J2 to amplifier 36 and voltage control oscillator 40, shown in FIG. 6, is connected to oscillator 38 at J3. For a specific desired metal output, such as gold, induction furnace 10 is tuned using power amplifier subassemblies 36, 38 and 40 shown in Fig.'s 3, 5 and 6 to produce a 13 kHz sine wave. Once the desired wave shape and frequency is set, tuning switch 34 is opened and run switch 32 is again closed. A single phase 220 volt supply is then applied at J5 to the power supply circuit 30 shown in FIG. 4 which connects to induction furnace 10 at J4, shown in FIG. 1, started at zero and slowly ramped up to 400 watts using Variac control 28.

Beaker 18 is loaded to metal level 20, shown in FIG. 2, approximately 2/3 full, with scrap metal segments, which have been peeled from the circuit boards and chopped into approximately 10 centimeter long chunks 22. Chemical solution 24, which is a mild HCL, preferably muratic acid, and water with an approximate ratio of 1/3 muratic acid and 2/3 water that has been saturated with copper sulfate is then added to beaker 18 to fill level 26, shown in FIG.2. As chemical solution 24 heats up to approximately 25 degrees centigrade and expands to run level 42, shown in FIG. 2, the frequency will raise to approximately 30 kHz., reflected energy drops from 5 to 1 down to 1 to 1 and the copper molecules are sheared very rapidly and then the nickel or zinc ions are sheared away from the gold plating. It is important to avoid driving the RF source into a square wave as square waves make the process unstable. Sine waves are ideal for this process. As the

copper and nickel molecules are sheared from the gold surface and absorbed by chemical solution 24, chemical solution 24 changes color from its natural aqua to a dark purple in approximately two minutes. At this point beaker 18 is removed from the induction furnace10 and the used chemical solution 24 is poured off to a precipitation tank, not shown. Fresh chemical solution 24 is added to beaker 18, beaker 18 is reintroduced to induction furnace 10 and the field is reapplied. This process is repeated two to five times until chemical solution 24 maintains its original color throughout the cycle. At that point the remaining metal, in this case gold, flake will float to the surface of beaker 18 and can be skimmed off or strained from chemical solution 24, rinsed in water and denatured alcohol, compressed and melted into bars or nuggets as 99.5 % pure gold.

An alternative embodiment that demonstrates this invention for gold reclamation is described as follows: a small, 2 kilowatt induction furnace 10 as shown in Figure 1A, is modified as the embodiment shown in Figure 1 except in addition to the grid drive control circuit shown there, this embodiment adds a cathode drive control circuit 46 which is switched in at interconnect point X shown in Figure 1A to provide more precise wave form shaping. Even though this drive scheme requires much higher power it generates an almost perfect wave form with no distortion or clipping and allows the shearing process to progress at a very rapid rate.